



Passive Measurement of CO₂ Column from an Airborne Platform

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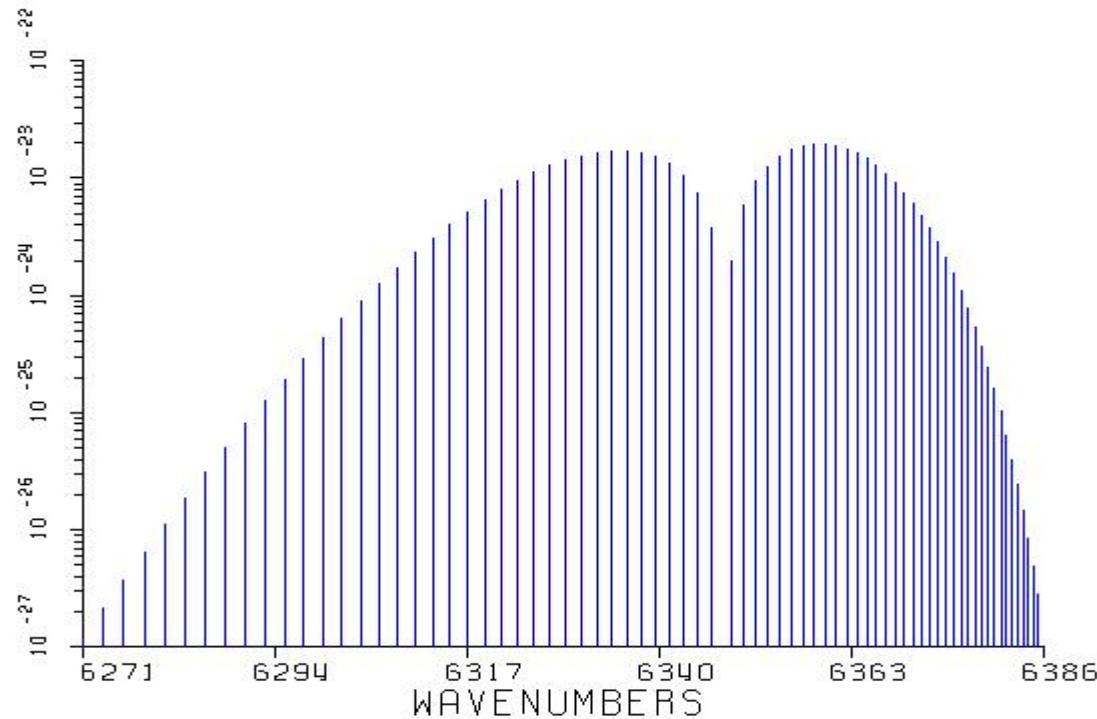
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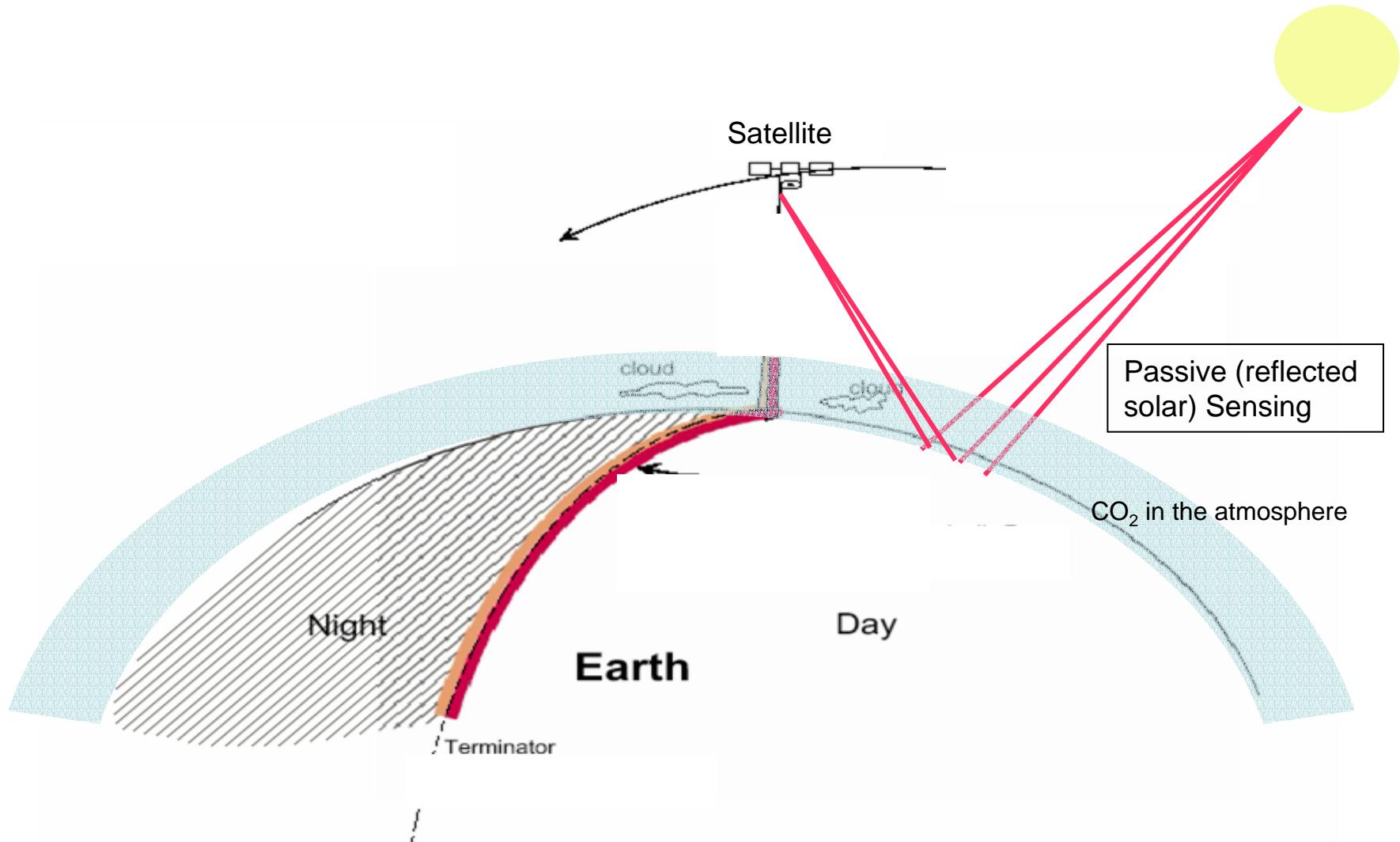
Objective

To construct a prototype instrument for deployment on aircraft that will demonstrate the feasibility of an innovative technique for measuring column average CO_2 from space with precision $>.3\%$. No measurement from space has ever achieved this level of precision



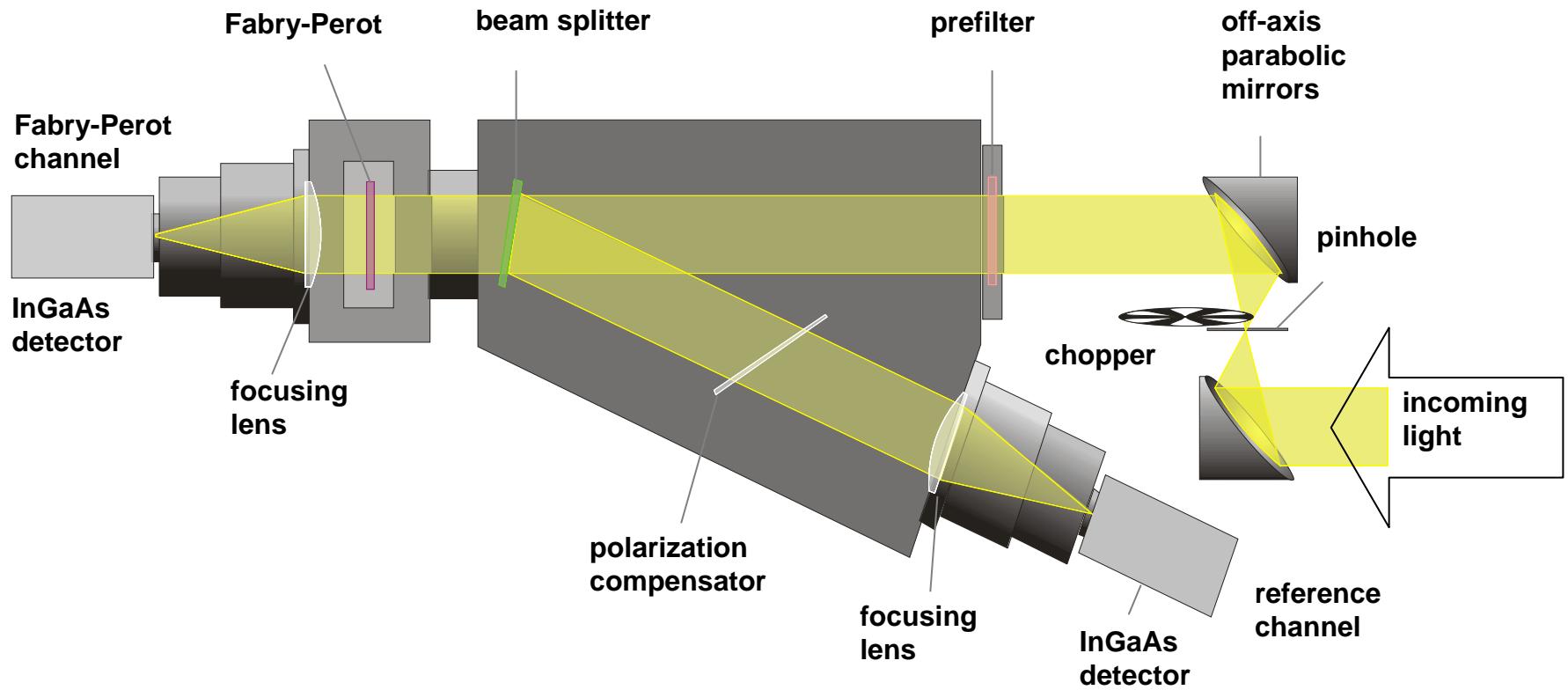


Space-based Measurement Approach



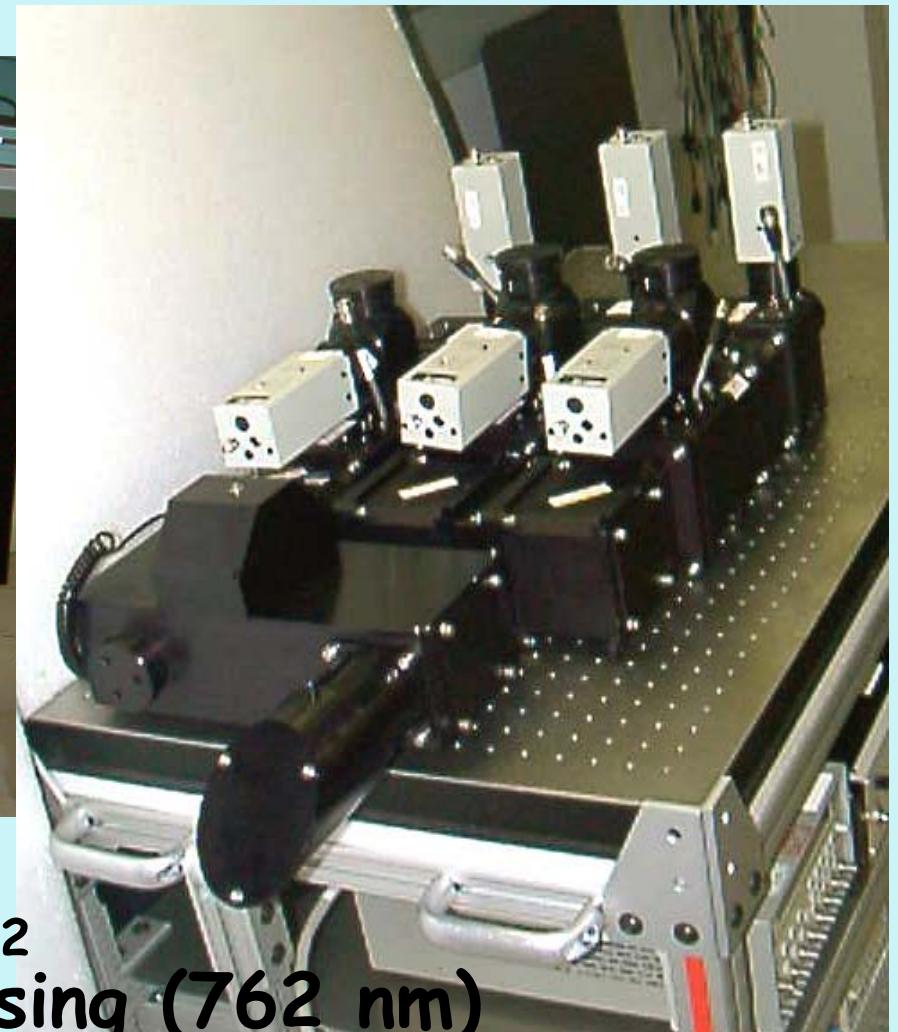


Instrument Design





The flight hardened version

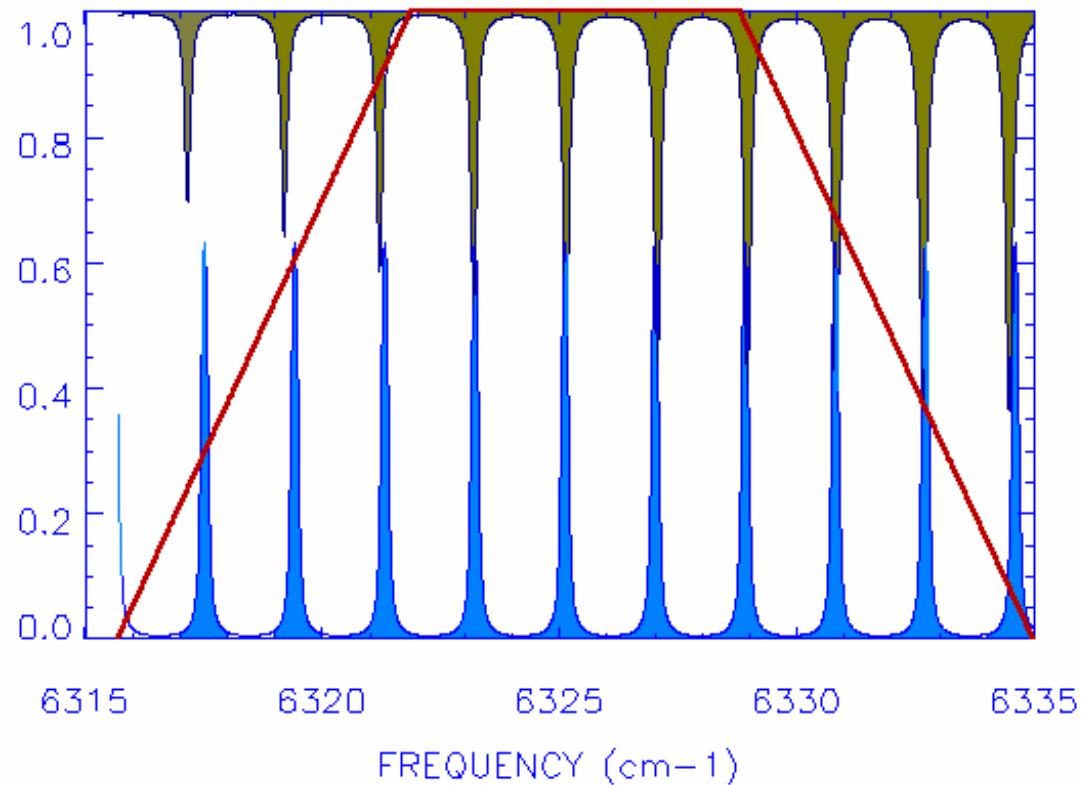


Channels for measuring CO_2
(1571 nm), O_2 pressure sensing (762 nm)
and O_2 temperature sensing channel (768 nm)

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Model for the CO_2 channel Overlap of Fringes and CO_2 Lines



FUSED SILICA FP ETALON .191 CM THICK
FINESSE=10

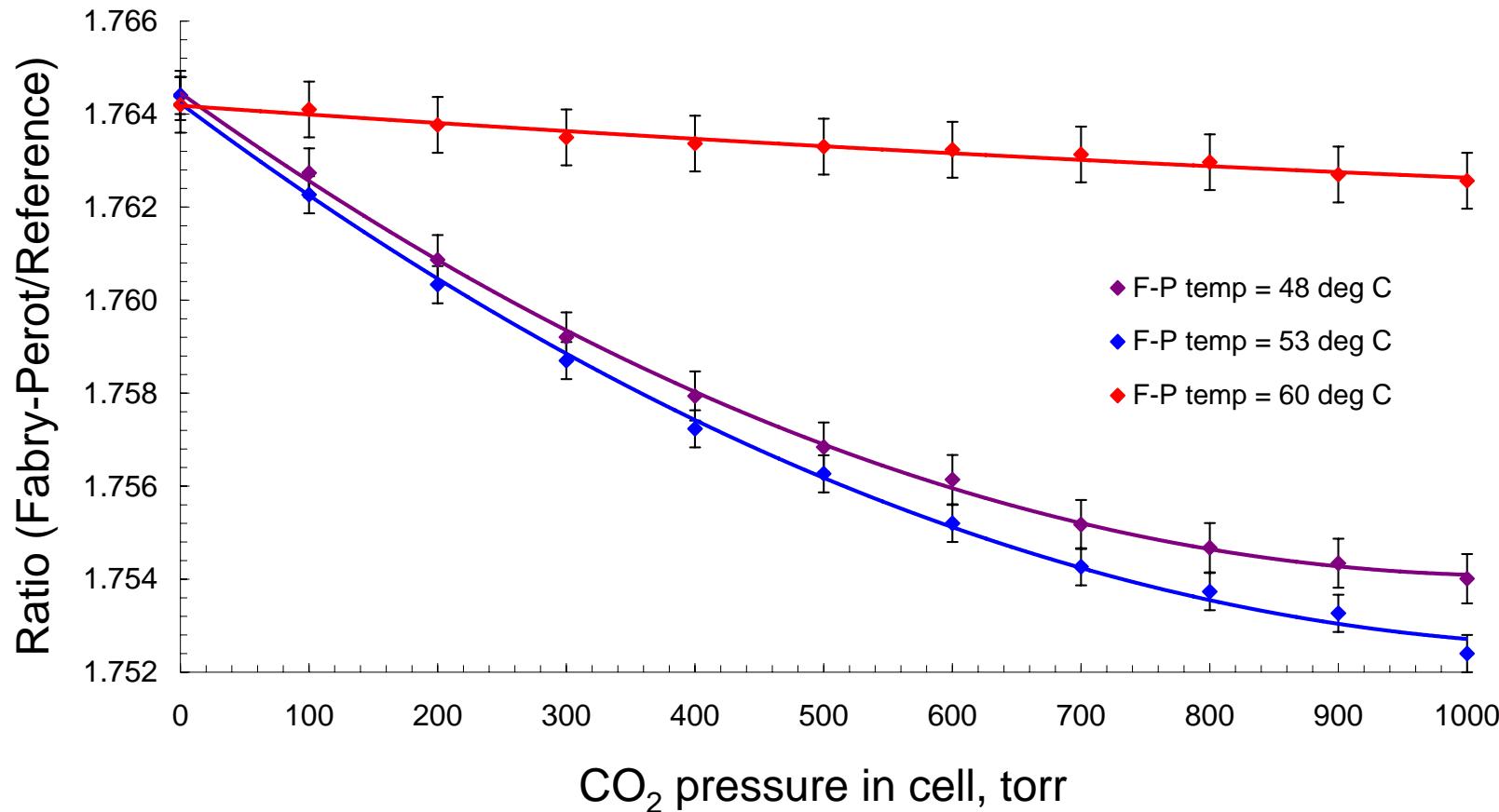
SENSITIVITY=1565

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REFLECTIVE



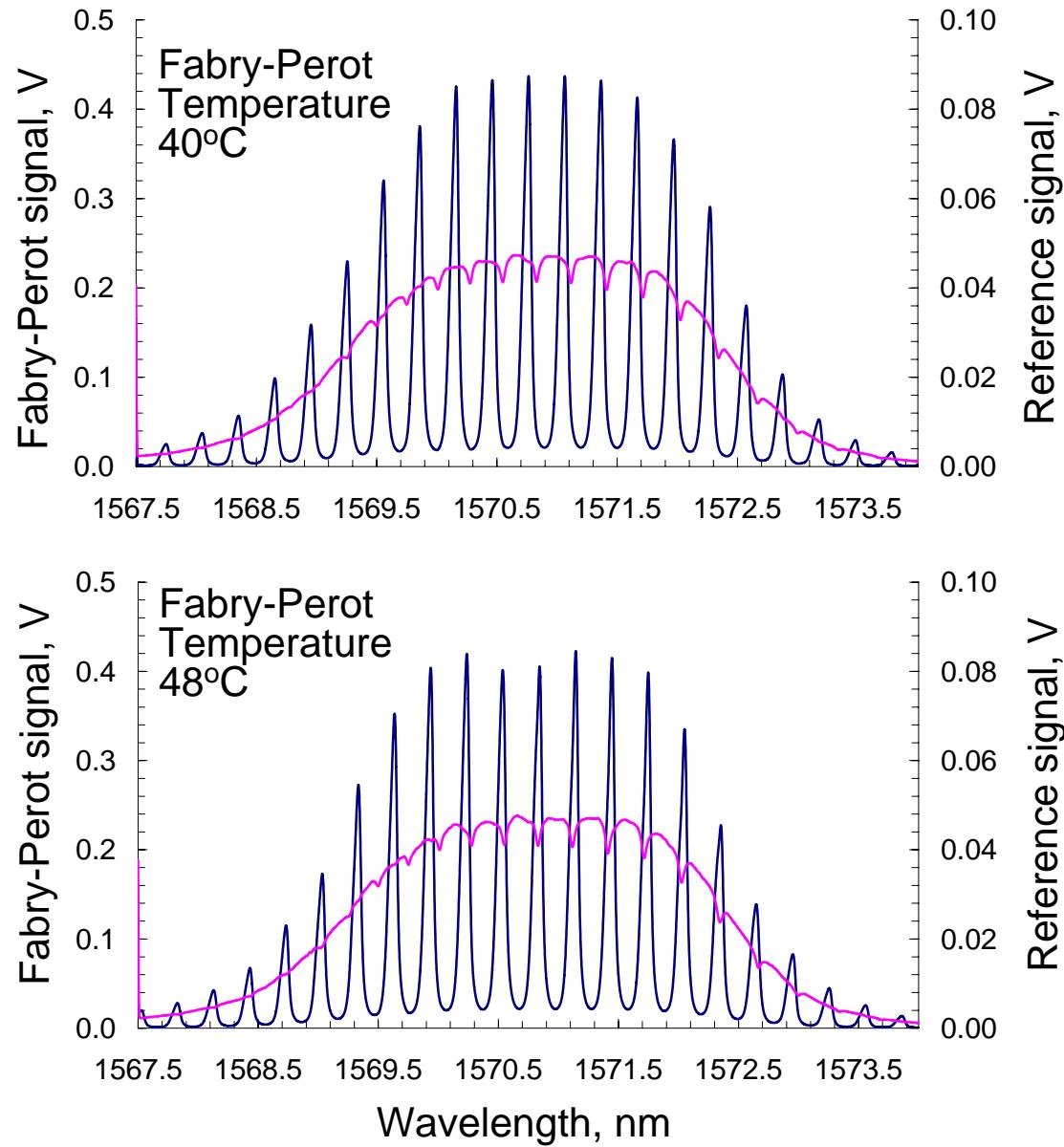
Ratio as a Function of CO_2 Pressure





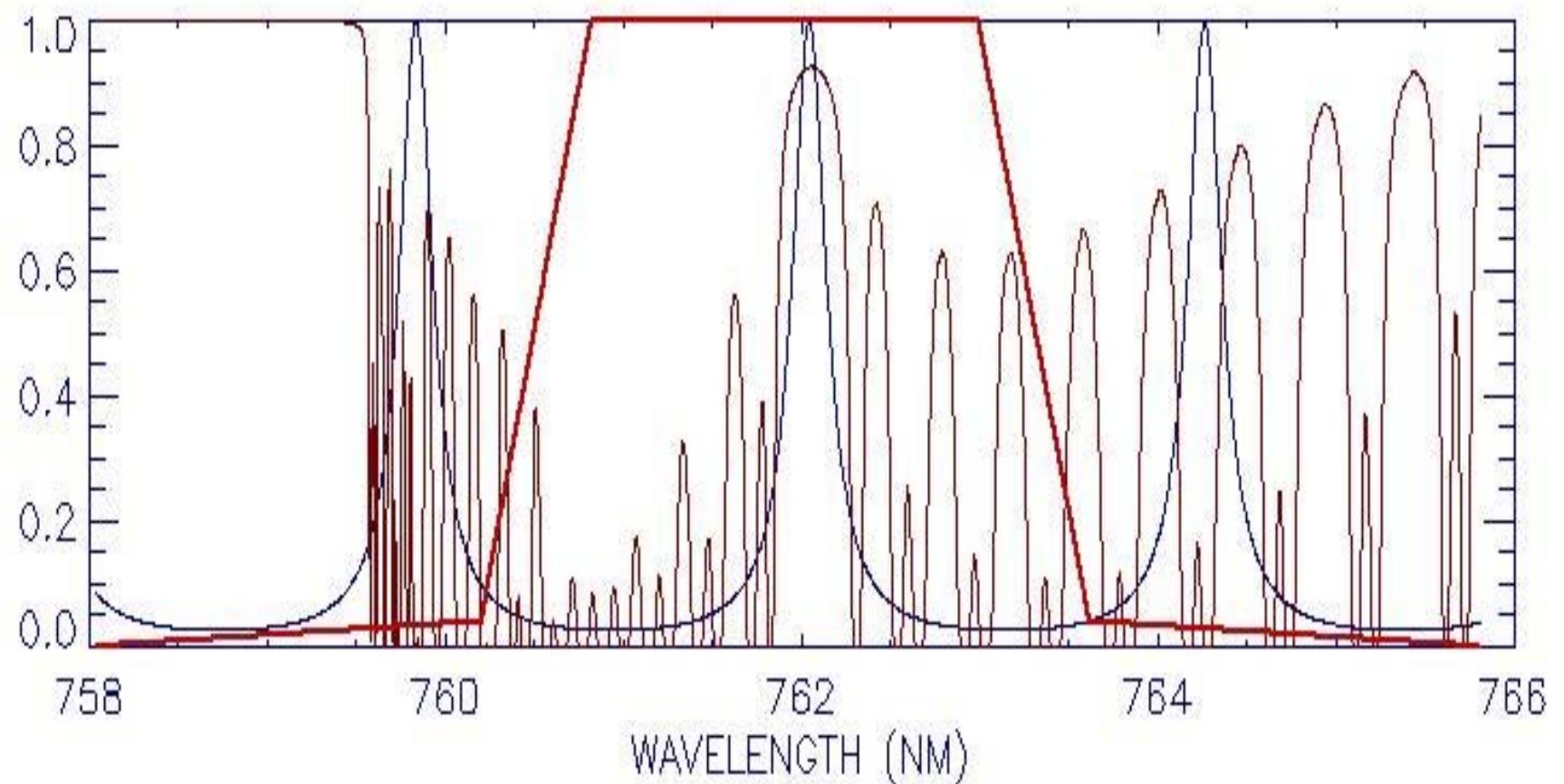
CO₂
channel

Comparison of Overlap at Two Temperatures



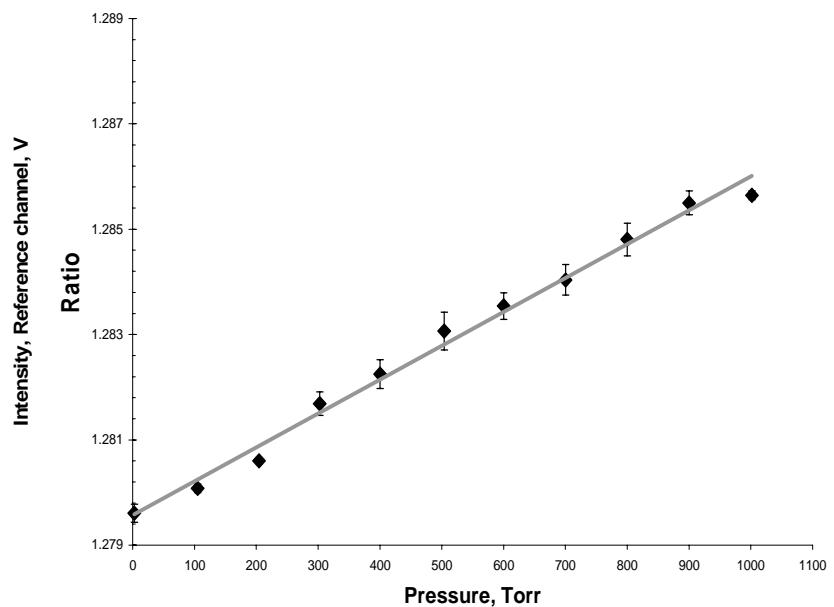
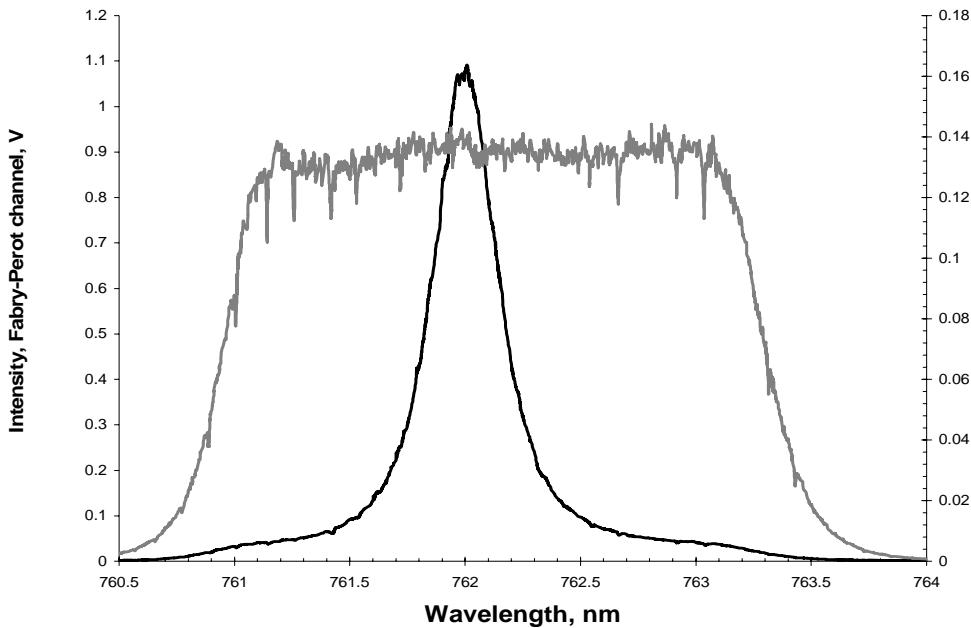


Theoretical depiction of the operation of the O_2 sensing channel





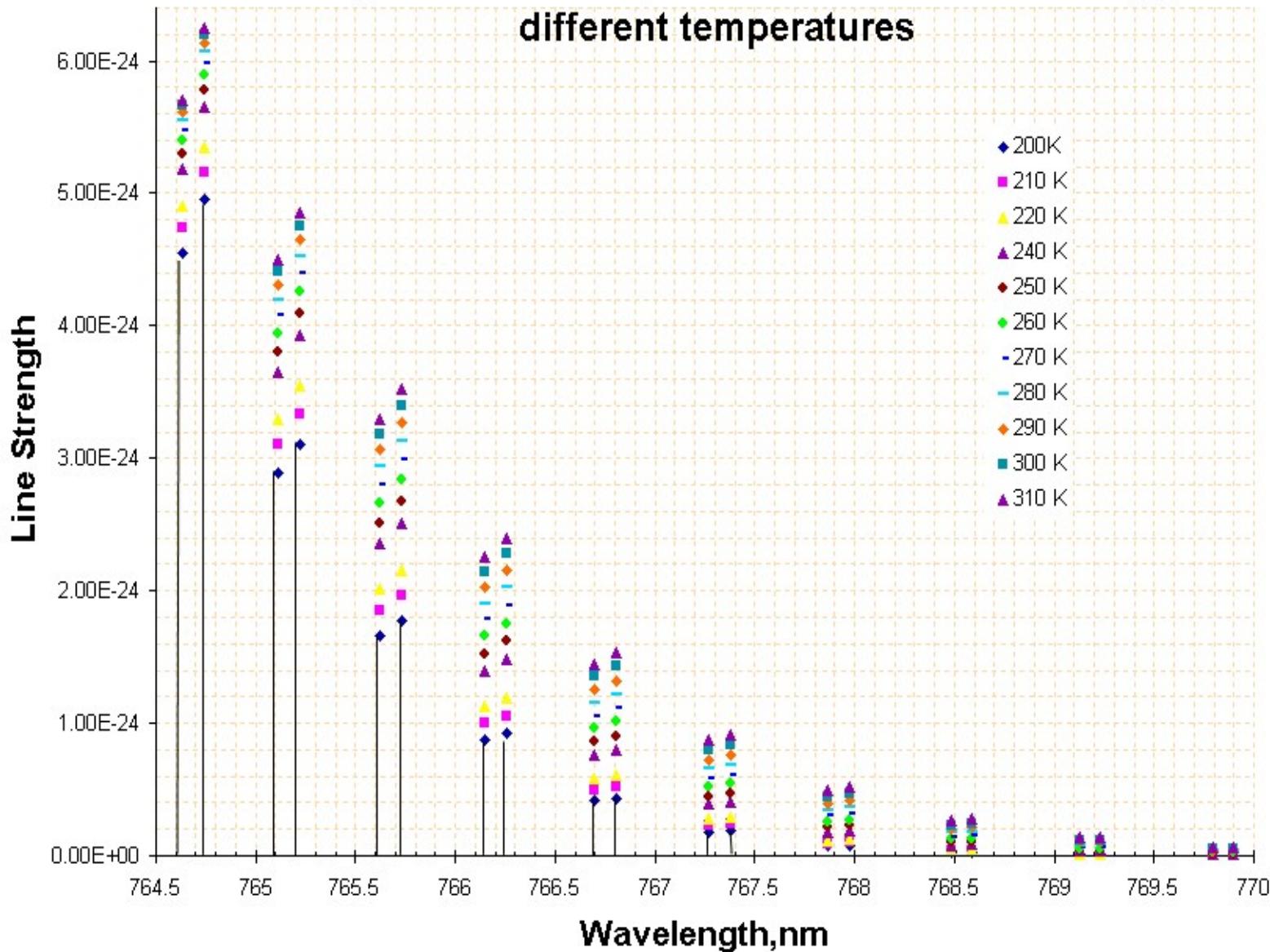
O₂ Pressure sensing channel, etalon temperature 22 deg C



- At the temperature 22 deg C the transmission band of the etalon can be placed in the gap at 762 nm and in this way only the Reference channel will be sensitive to pressure changes.
- Ratio as a function of O₂ pressure in the gas cell, the etalon is at 22 deg C

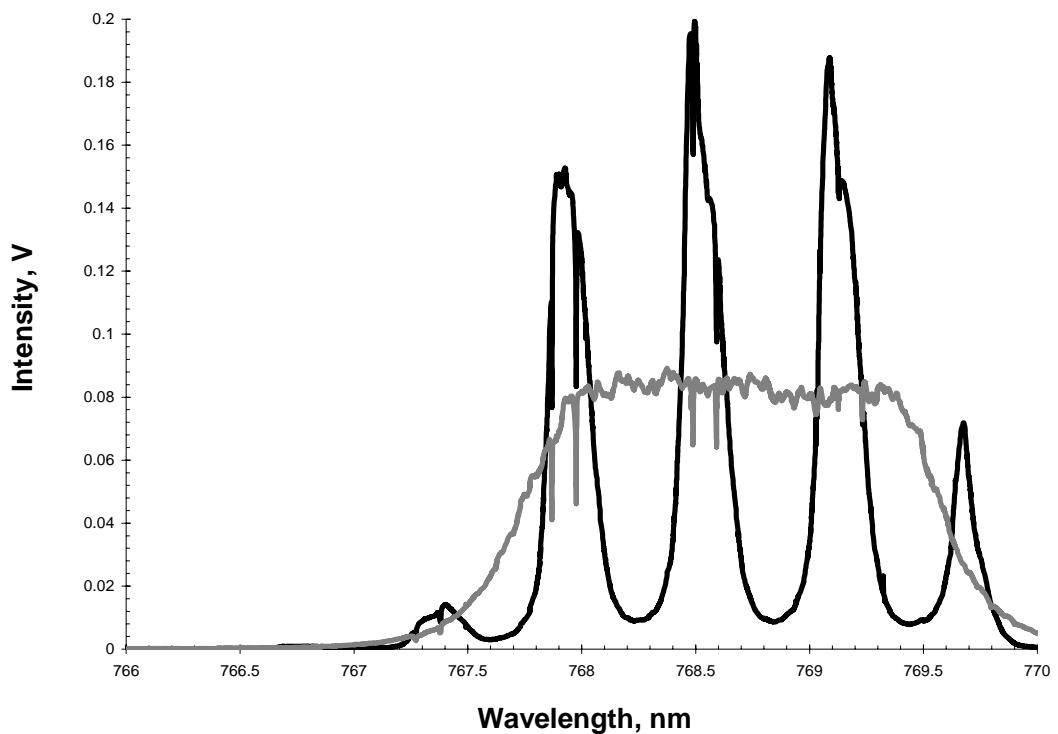


Line Strength of the absorption lines for molecular oxygen at different temperatures





O₂ Temperature sensing channel, etalon temperature 71 deg C





Assembling the instrument in Edwards AFB



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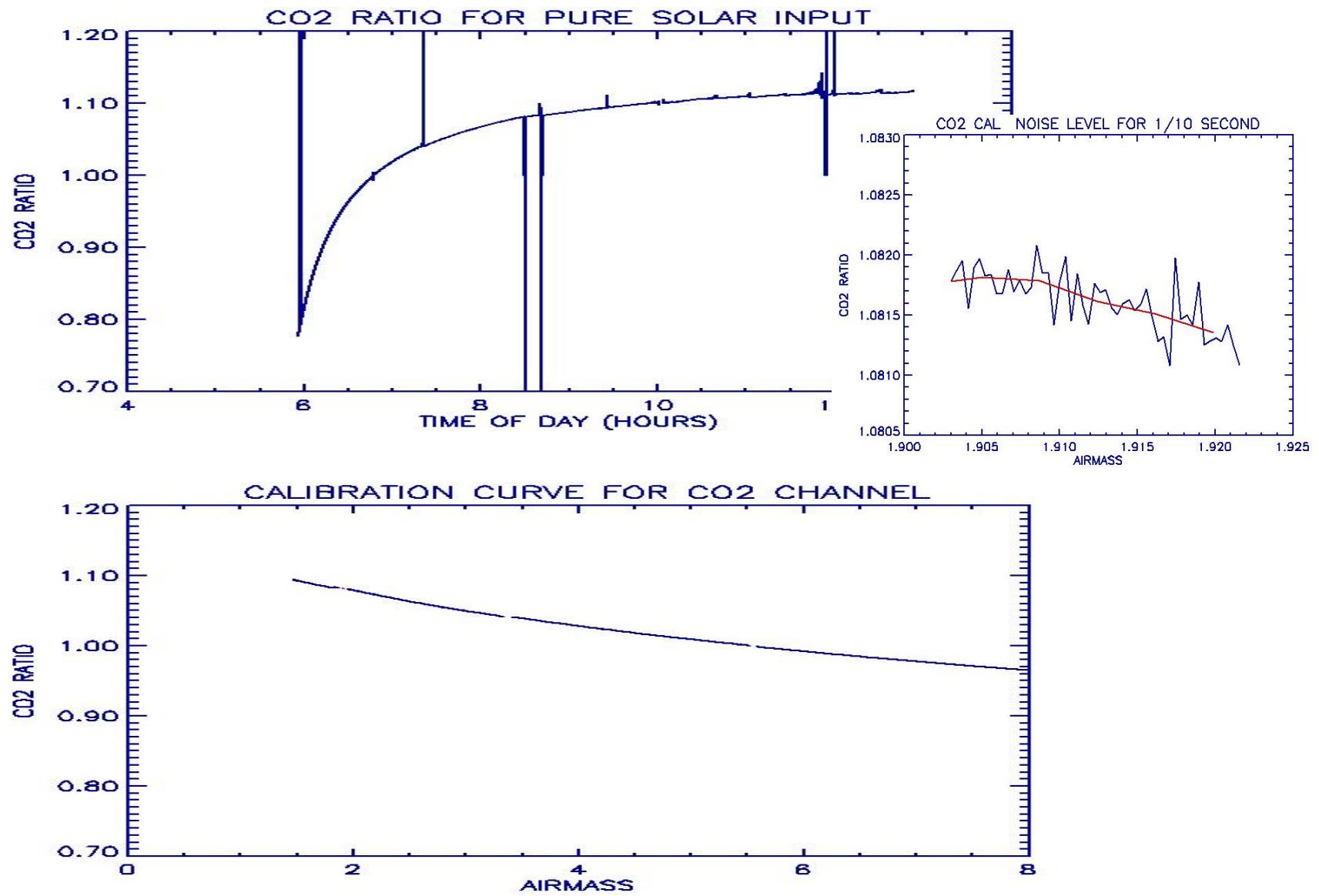
Ground testing results with the fiber-coupled Sun Tracker



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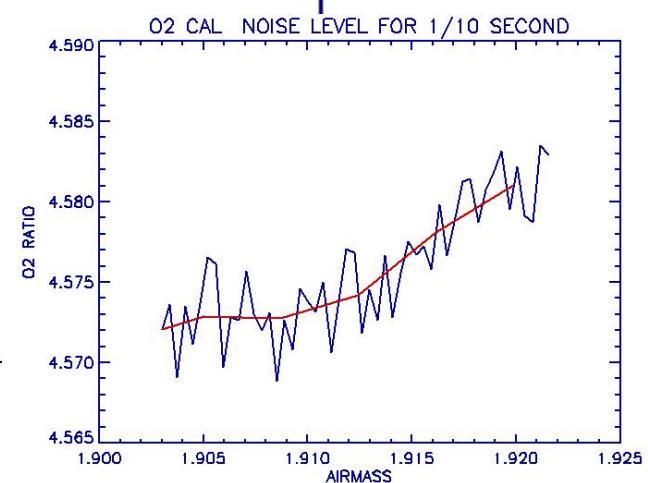
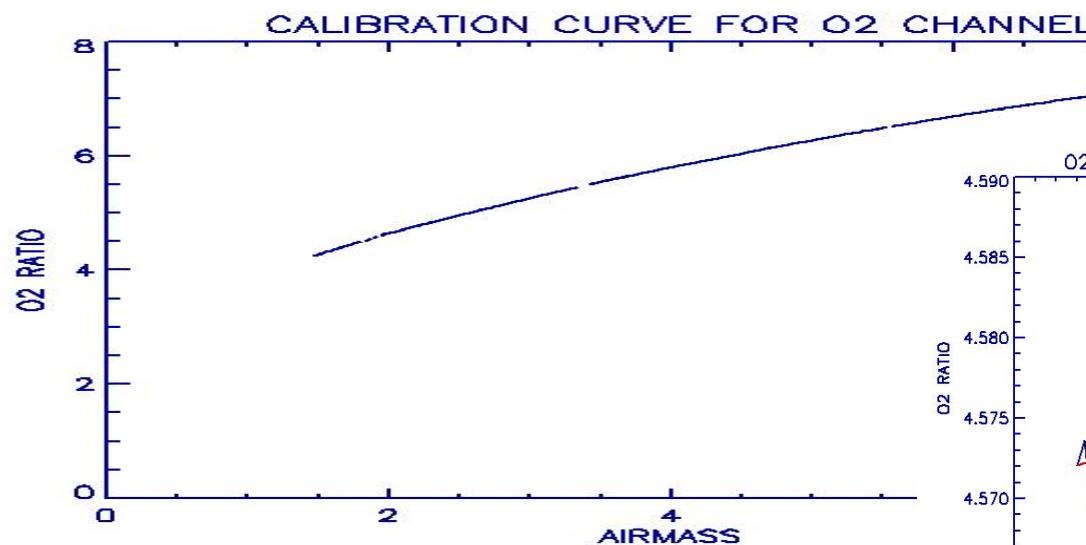
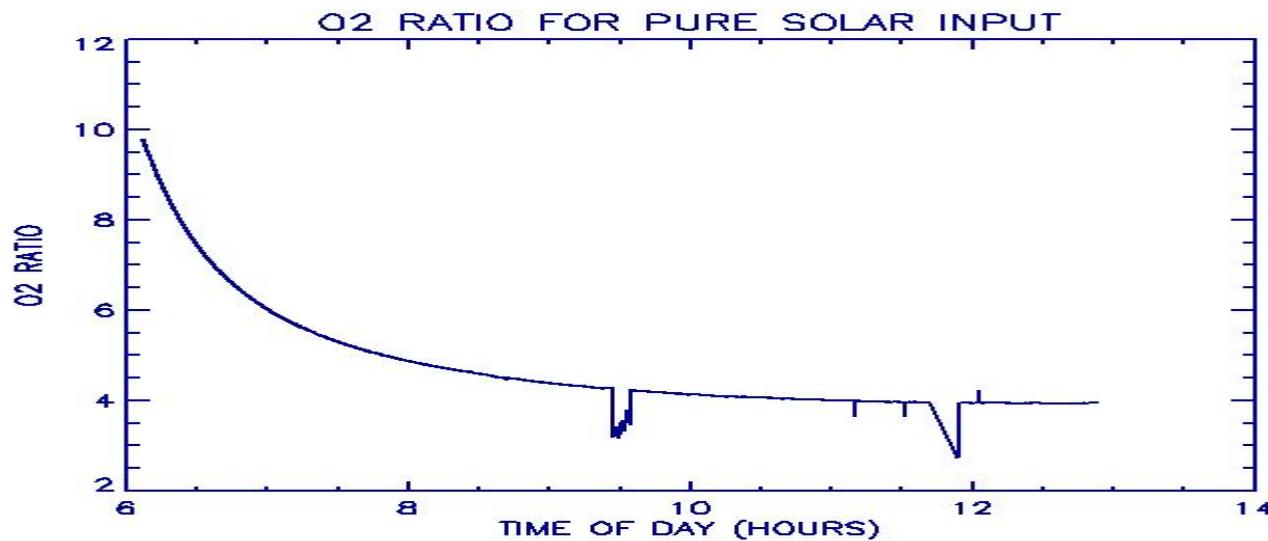
Calibration using Direct Sun CO₂



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Calibration using Direct Sun O₂



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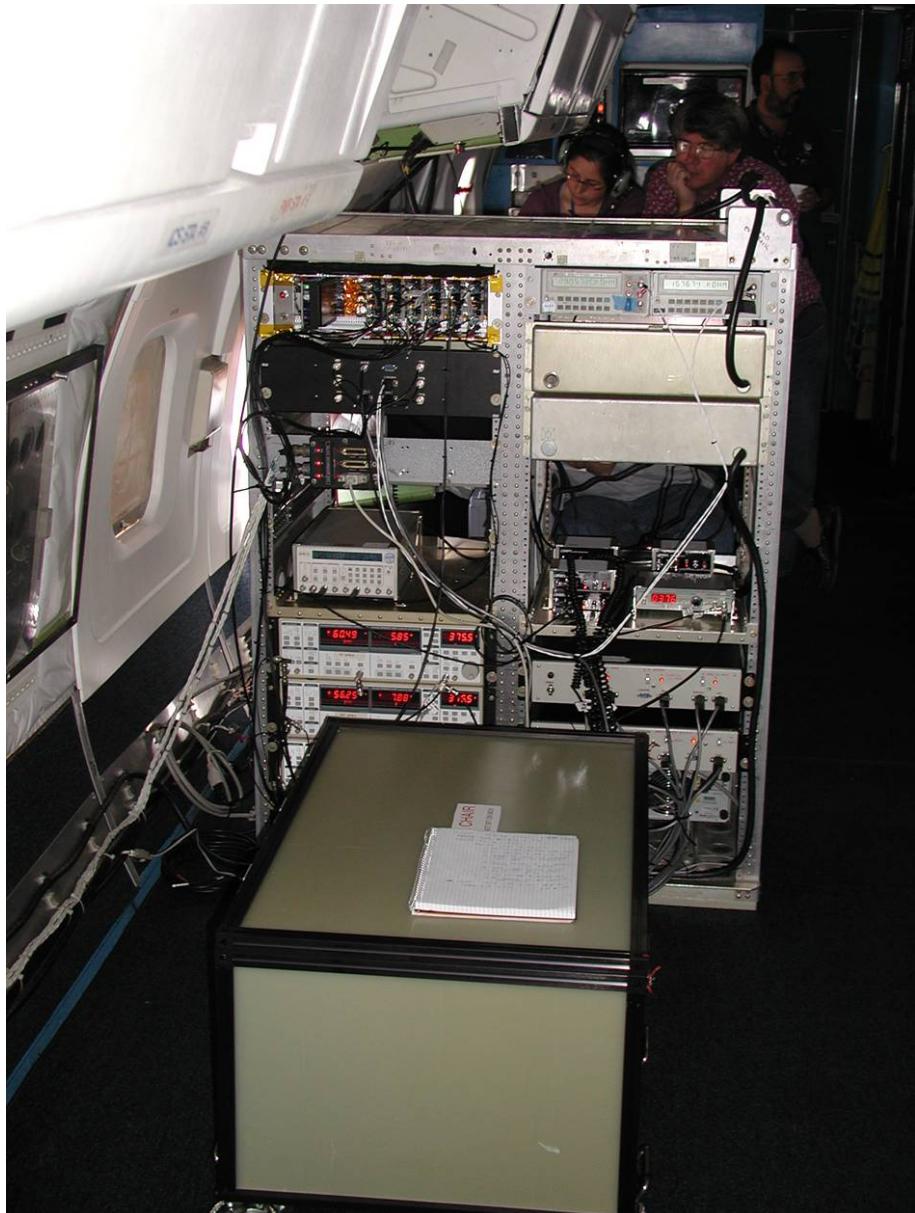
NASA's Airborne Science DC-8



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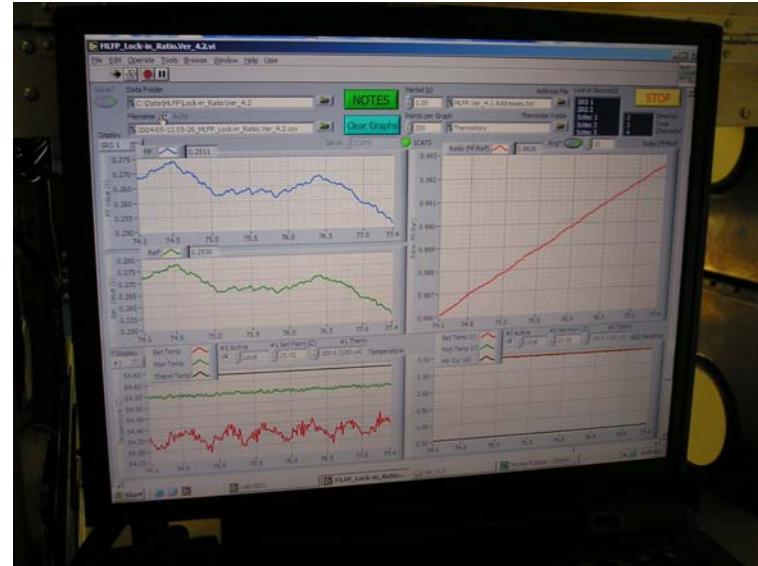
FPICC rack and instrument shown installed in DC-8 cabin





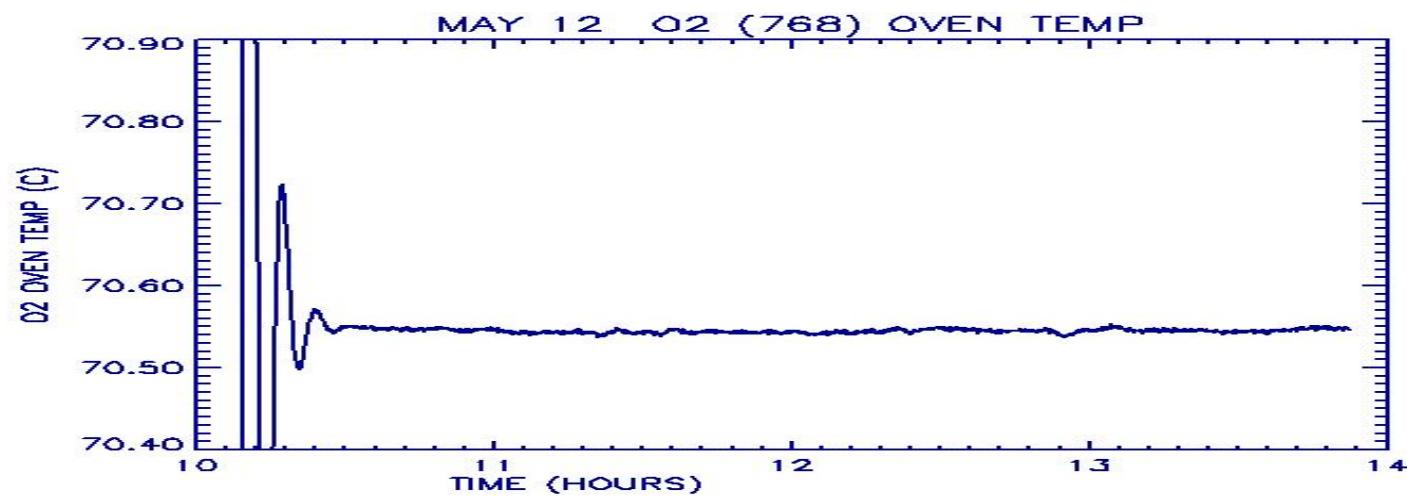
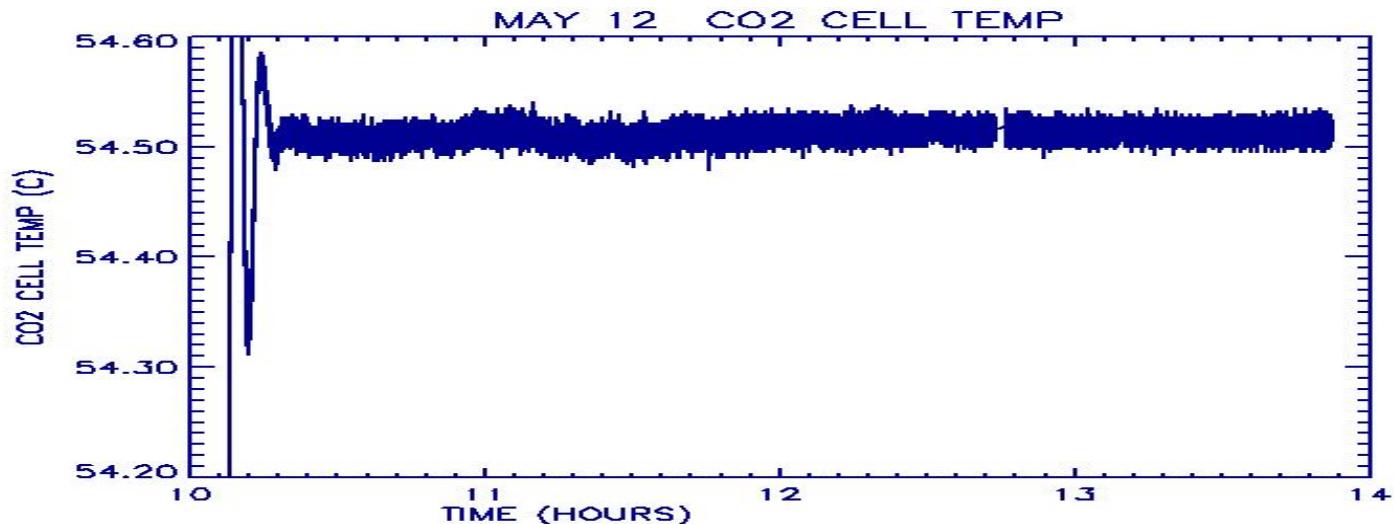
Test Flights

- | | |
|--------|--------------------------|
| May 11 | Local Dryden (2 hours) |
| May 12 | Central Valley (4 hours) |
| May 14 | Central Valley (4 hours) |
| May 17 | Southern Idaho (3 hours) |



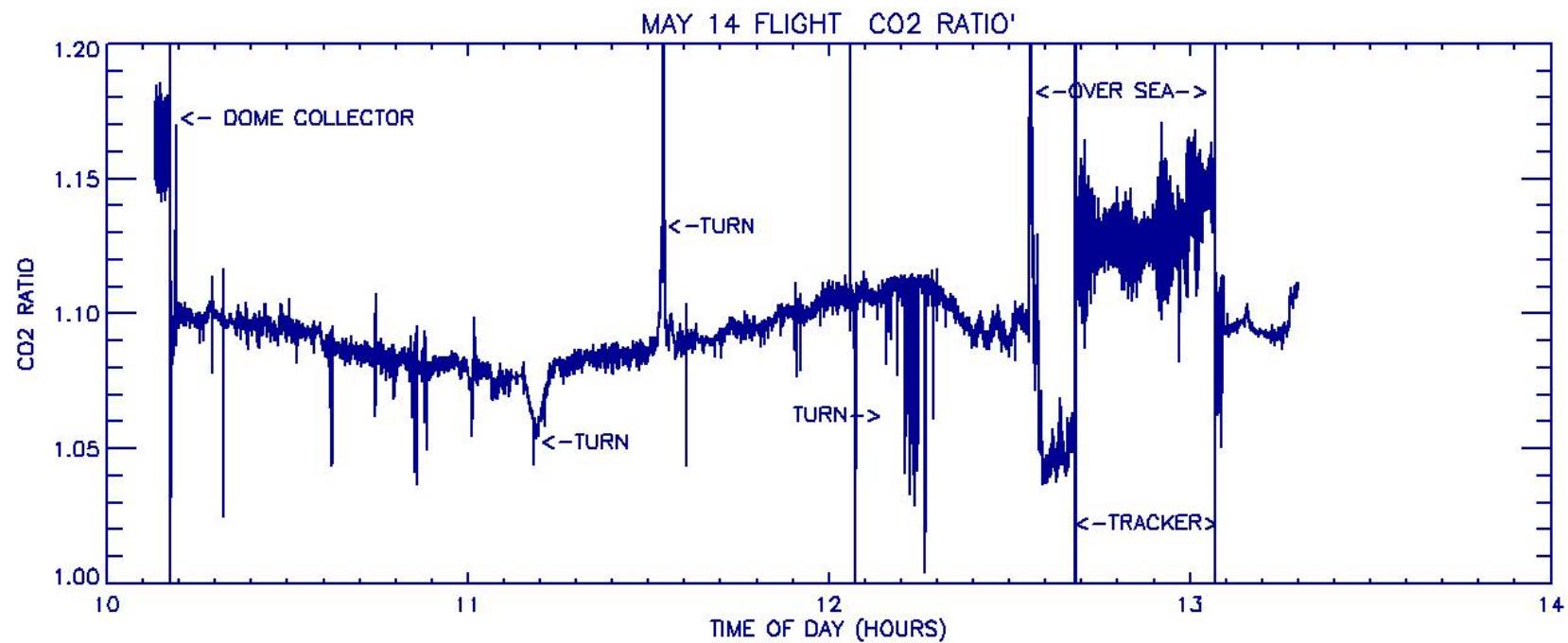


Oven Performance Checks



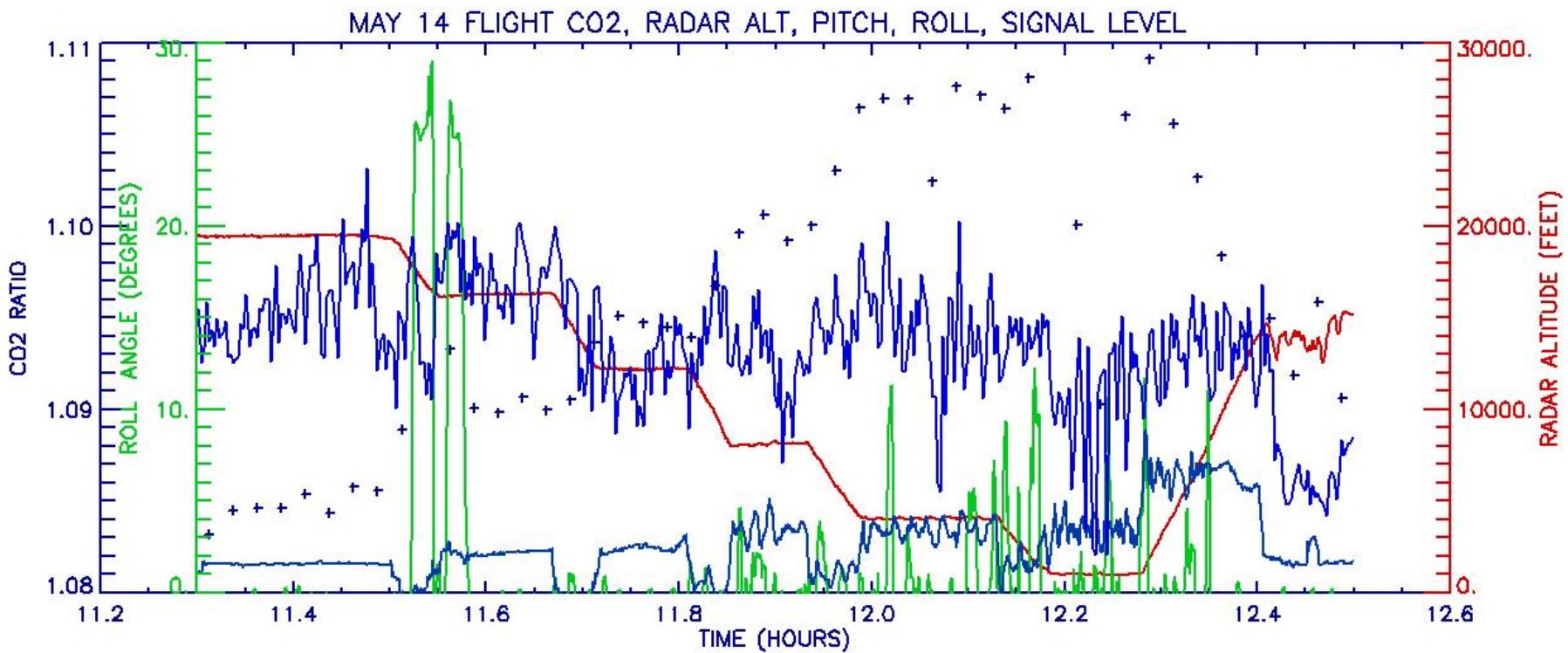


May 14 Test Flight



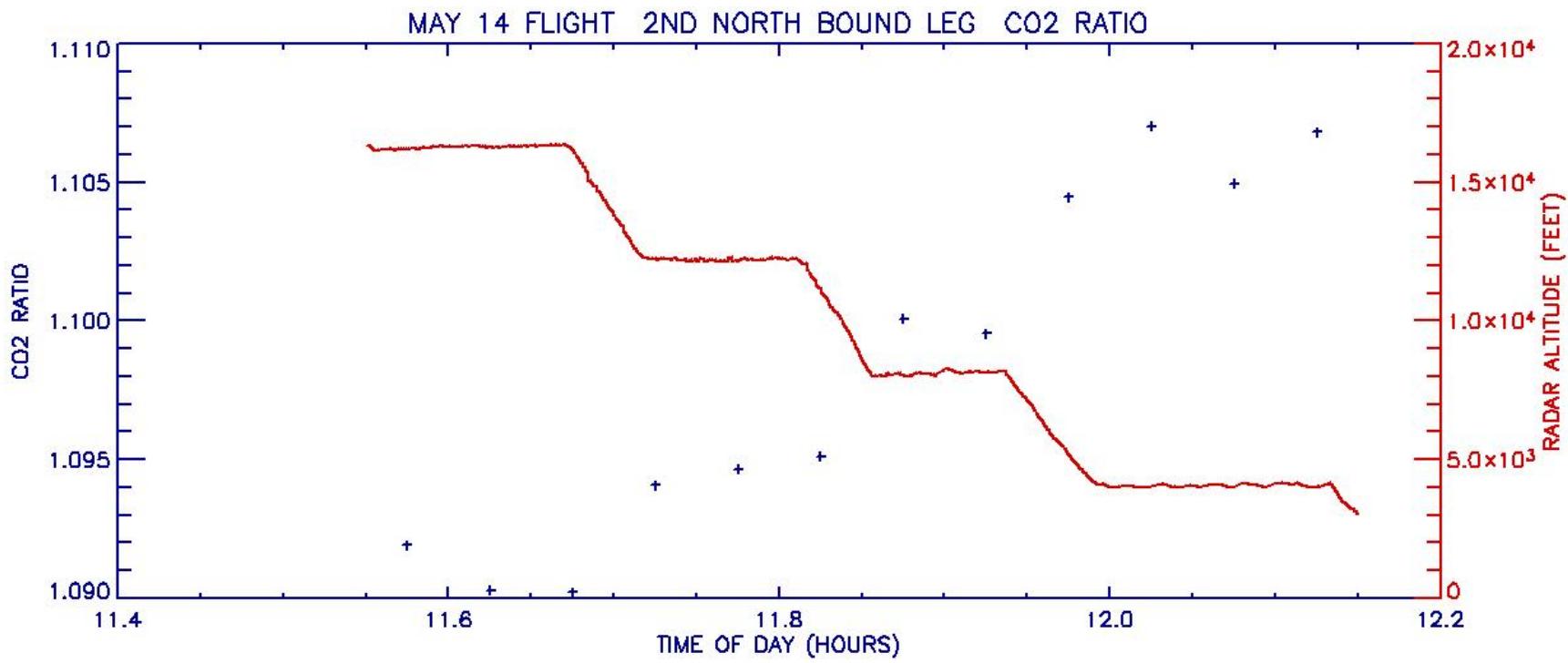


May 14 Test Flight



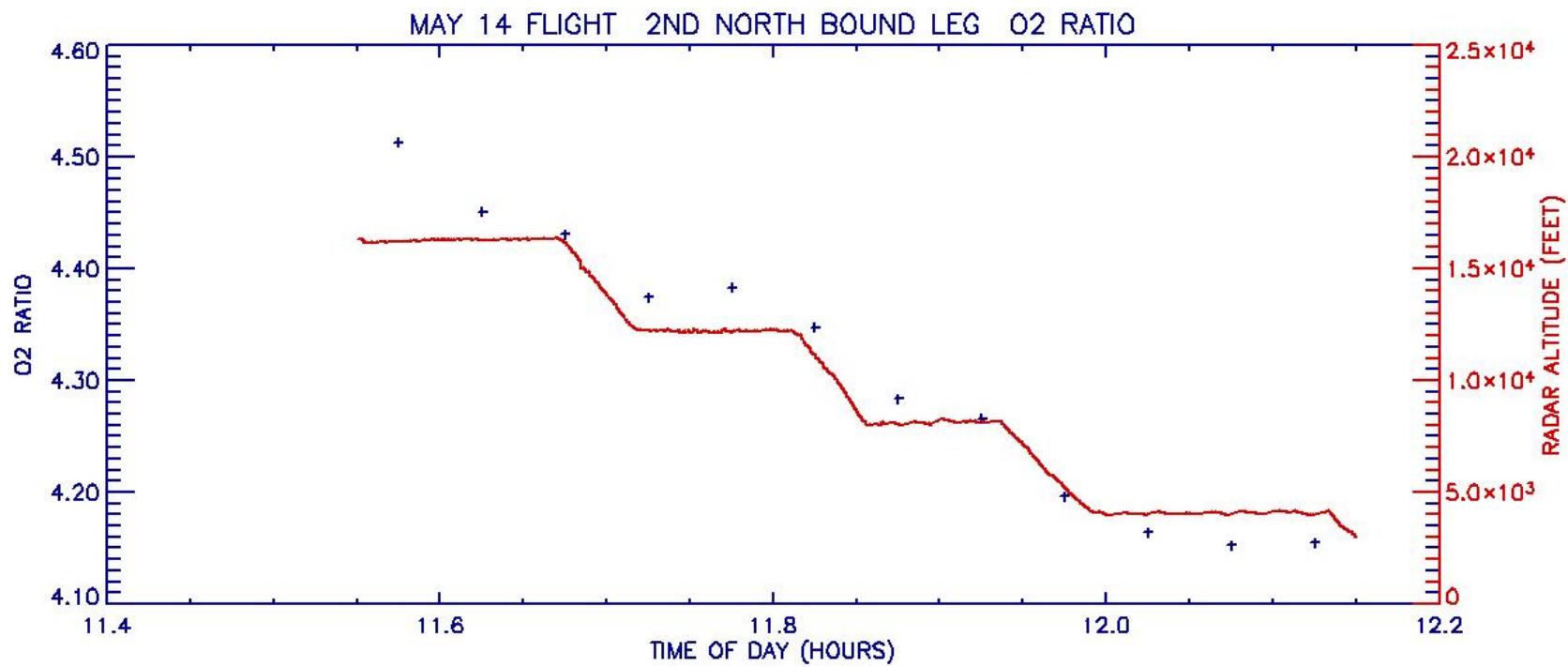


May 14 Test Flight



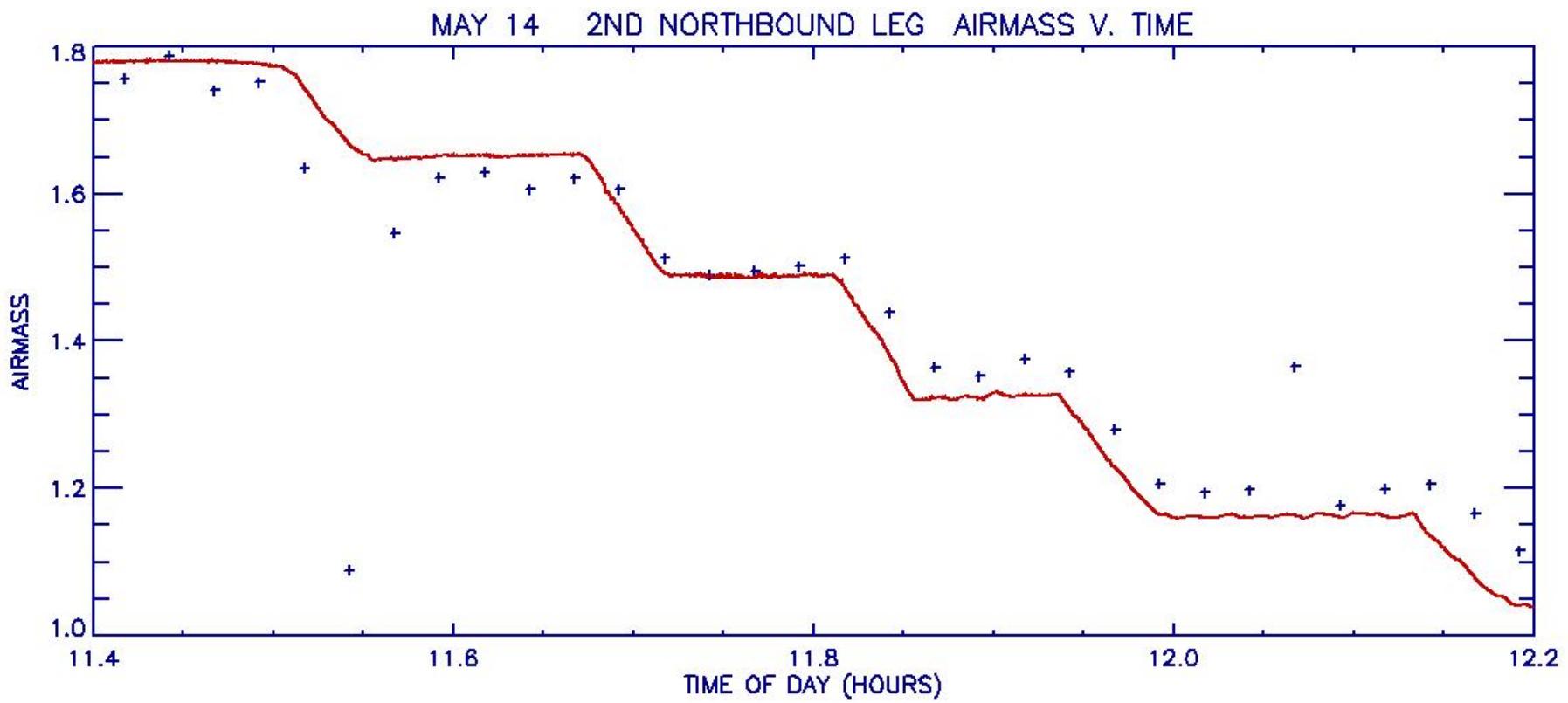


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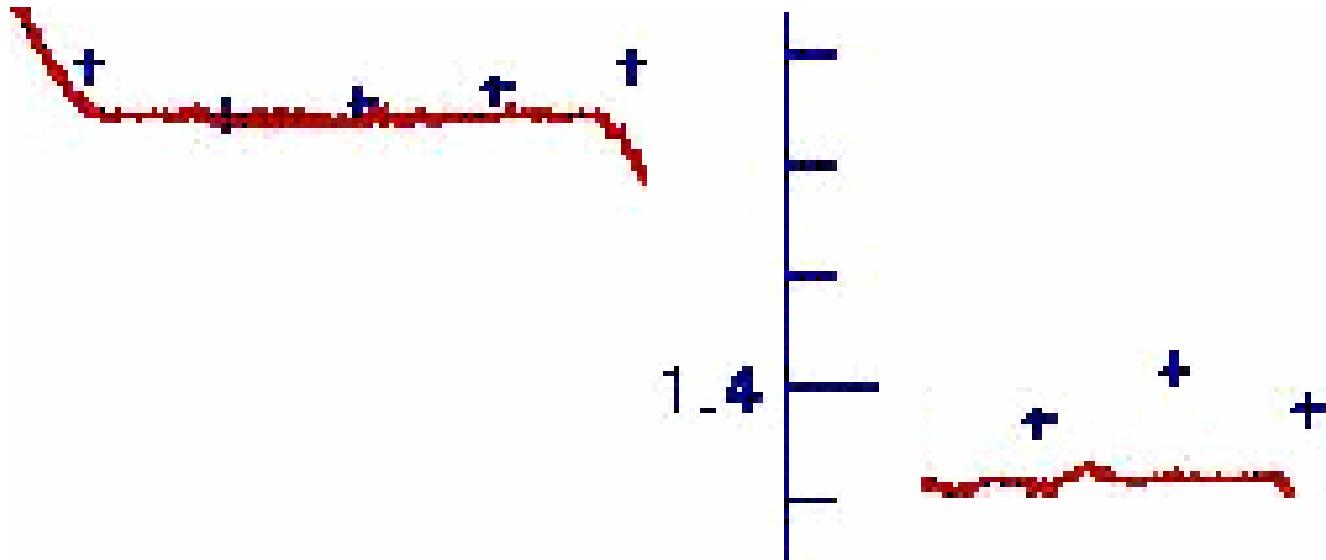


May 14 Test Flight





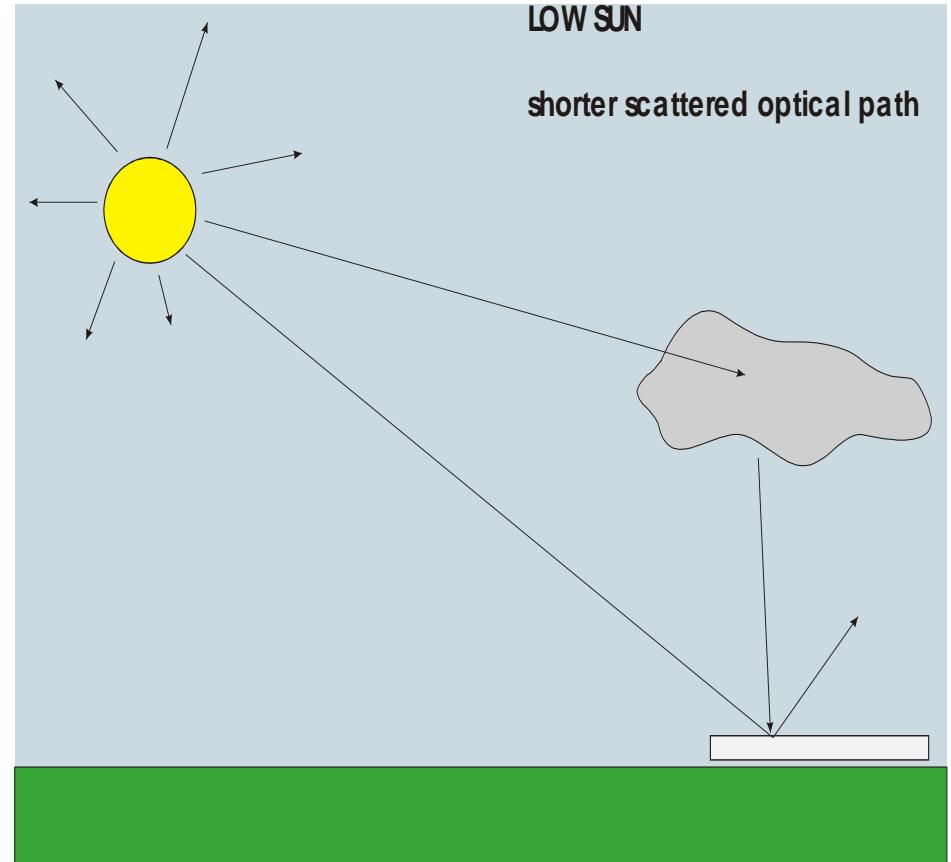
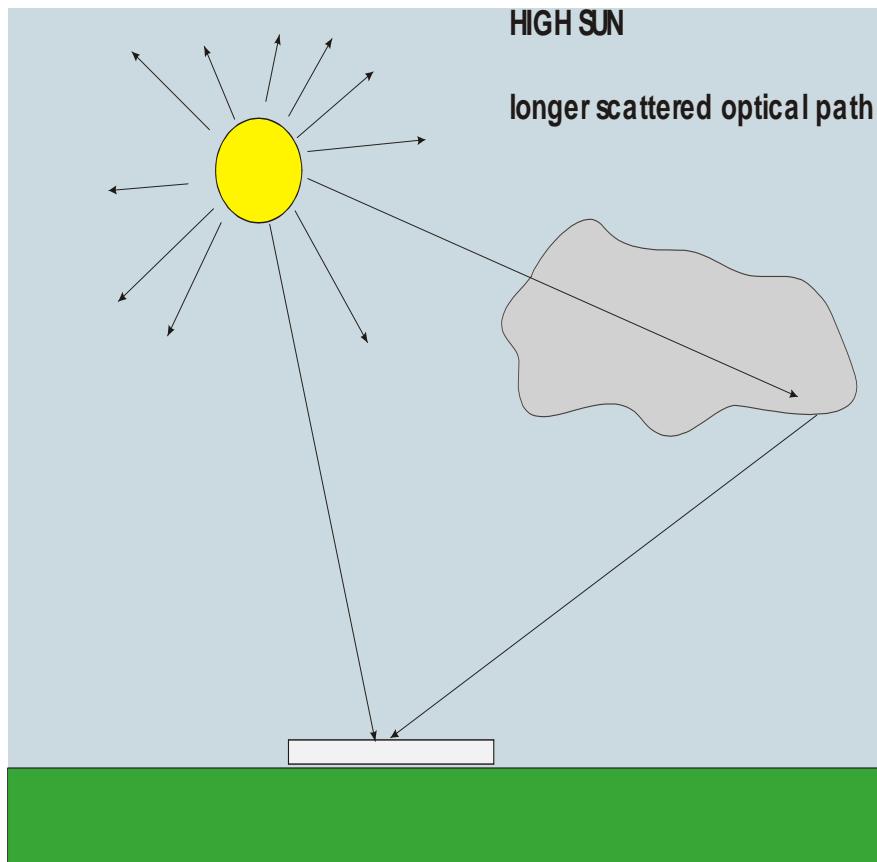
Blown up section of Air Mass Plot



Point to point variation is $\sim .05$ for total air mass of 1.4. This represents an error of $\sim 3.5\%$ for these 90 second samples.



ATMOSPHERIC SCATTERING ALTERS THE OPTICAL PATH

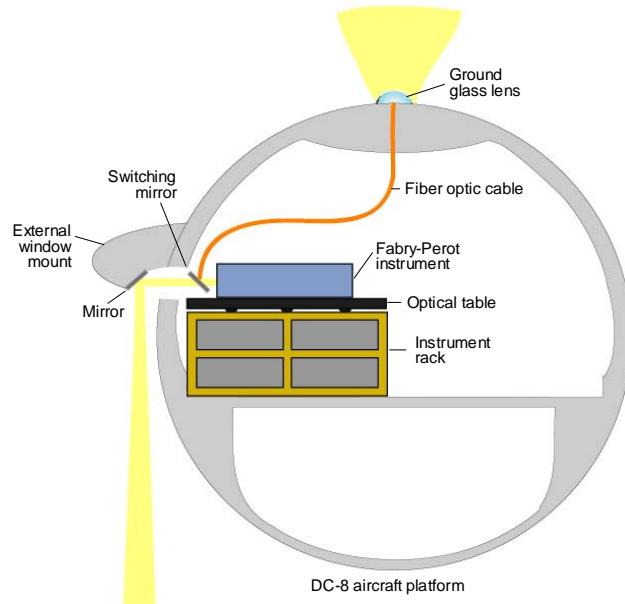




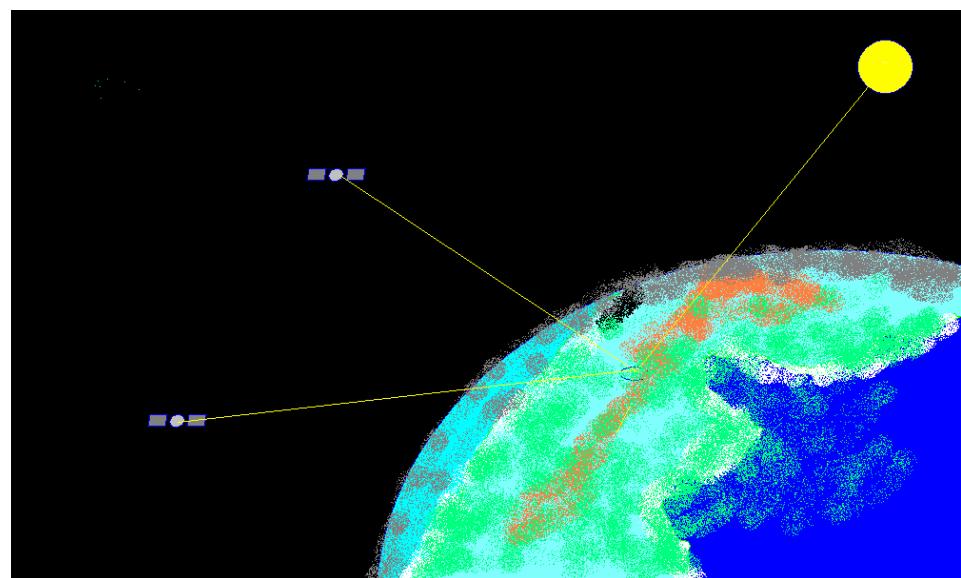
Dealing with Atmospheric Scattering I

Most variation in path length arises on the way down

- So—use two different measurements with the same downward path but different upward path and take the difference.
 - On an aircraft have a downward and an upward looking system (works if scattering is above)
- Use 2 satellites observing the same point



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Dealing with Atmospheric Scattering II

USE THE GLINT!

GLINT IS REFLECTION OF SUNLIGHT OFF THE SURFACE OF WATER—ADVANTAGE IS THAT YOU KNOW THE PATH LENGTH FOR GLINT.

GLINT CAN BE AS MUCH AS 1,000,000 TIMES BRIGHTER THAN REFLECTION OFF GROUND



SUMMARY & STATUS

- INSTRUMENT FOR SIMULTANEOUS MEASUREMENT OF CO₂ AND OXYGEN DEMONSTRATED IN FIELD WITH VERY HIGH INTRINSIC PRECISION.
- PATH LENGTH UNCERTAINTY DUE TO ATMOSPHERIC SCATTERING REDUCES PRACTICAL PRECISION.
- SCATTERING PROBLEMS CAN BE SOLVED WITH EFFORT
- SMALL, INEXPENSIVE, SYSTEM CAN BE ADAPTED FOR GROUND BASED, AIRCRAFT, OR SATELLITE USE.
- FUTURE WORK AIMED AT VERIFYING TECHNIQUES FOR DEFEATING SCATTER, STABILIZING DESIGN, AND EXTENDING TECHNIQUE TO OTHER SMALL MOLECULES



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